The Lightning Imaging Sensor on the Tropical Rainfall Measuring Mission

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The lightning imaging sensor (LIS) is a small, calibrated optical instrument designed to investigate the global incidence of lightning, its correlation with ice and precipitation, and the global electric circuit. Conceptually, LIS is a simple device, consisting of a staring imager optimized to detect and locate intracloud and cloud-to-ground lightning with storm scale resolution over a large region of the Earth's surface, to mark the time of occurrence, and to measure the radiant energy. From the tropical rainfall measuring mission (TRMM) orbit, it will monitor individual storms within its field of view (FOV) for over 60 sec, long enough to estimate the lightning flash rate. Location of lightning flashes will be determined to within 5 km over a 600- by 600-km FOV.

The LIS design uses an expanded optics wide-FOV lens, combined with a narrow-band interference filter that focuses the image on a small high-speed, charge-coupled-device focal plane. The signal is read out from the focal plane into a real-time event processor for event detection and data compression. The sensor design results from the requirement to detect weak lightning signals during the day when the background illumination, produced by sunlight reflecting from cloud tops is much brighter than the illumination produced by lightning.

A combination of four methods is used to take advantage of the significant differences in the temporal, spatial, and spectral characteristics between the lightning signal and the background noise. First, spatial filtering is used to match the instantaneous FOV of each detector element in the LIS focal plane to the typical cloud top illuminated area by a lightning event. Second, spectral filtering is applied, using a narrow band interference filter centered about the strong OI (1) emission multiplet in the lightning spectrum at 777.4 nm. Third, temporal filtering is applied. The lightning pulse duration is on the order of 400 μsec, whereas the background illumination tends to be constant on a time scale of seconds. The lightning signal-to-noise ratio improves as the integration time approaches the pulse duration. Accordingly, an integration time of 2 msec is chosen to minimize pulse splitting between successive frames and to maximize lightning delectability. Finally, a modified frame-to-frame background subtraction is used to remove the slowly varying background signal from the raw data coming off the LIS focal plane. If after background removal, the signal for a given pixel exceeds a specified threshold, that pixel is considered to contain a lightning event.

LIS investigations will further our understanding of processes related to, and underlying, lightning phenomena in the Earth/atmosphere system. These processes include the amount, distribution, and structure of deep convection on a global scale, and the coupling between atmospheric dynamics and energetics. Lightning activity is closely coupled to storm convection, dynamics, and microphysics, and can be correlated to the global rates, amounts, and distribution of precipitation, to the release and transport of latent heat, and to the chemical cycles of carbon, sulfur, and nitrogen. Lightning is an unique indicator of deep convection and is the only means presently available to detect deep convection from space without a land-ocean bias. In this way, LIS will strongly support TRMM studies of the hydrologic cycle. It will continue the development of a thunderstorm and lightning climatological data base that has been started by the Optical Transient Detector (OTD).

The OTD, a predecessor of LIS, was launched on April 3, 1995. It has completely validated the LIS design concept, providing unique lightning data to the scientific community. For the first time, global lightning is available with high-detection efficiency and spatial resolution.

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Biographical Sketch: Dr. Hugh Christian is a senior research scientist with the Earth System Science Division. He obtained his Ph.D. in physics from Rice University in 1977 and began his career with Marshall in 1980.